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ABSTRACT

This paper begins with a discussion of the decision-making process. The application of operations research technologies to managerial decision-making is noted, and the development of management information systems in organizations and some limitations of these systems are discussed. An overview of the Human Information Processing System (HIPS) model and its three subsystems--external memory, short-term memory, and long-term memory--is then presented, and the concepts of problem space and bounded rationality are introduced. A description of the architecture of an expert system covers its two basic components: (1) the knowledge base and working memory; and (2) the inference system and control subsystem. Several applications of expert systems by library managers and operational groups are identified, and a prediction that expert systems will have a bright future in libraries and more user-oriented applications concludes the paper. (15 references) (MES)

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EXPERT SYSTEMS: A CONCEPTUAL ANALYSIS AND PROSPECTS FOR THEIR LIBRARY APPLICATIONS

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Abstract

Information is raw material for planning and decision making . Operations research and other modern management techniques are used for producing information for decision making. The concept behind these techniques which aim at optimization is under attack by the "Behavioristic School" of management science as unrealistic. The School asserts that instead of optimization decision makers resort to heuristics-adhoc mode of decision making. Heuristics are the result of cognitive strain which a decision maker experiences when the informational demand of a problem exceeds his information processing capacity. The current researches in hum,an information processing systems and in computer science led the Artificial Intelligence (AI) community to develop intelligent systems known as expert systems which may improve decision maker's heuristics. Expert systems are being developed for different library applications.

1. INTRODUCTION

Information is raw material for decision-making. A decision involves three things: (i) creation of concept of a desired state of affairs; what would we like the system to be? what are we striving for? what are the goals and objectives? (ii) there is the apparent state of actual condition; (iii) generation of action that will eliminate the discrepancy between the desired state and the actual condition. In general, the kind of action involved is conversion of that information into action which will eliminate the discrepancy between the desired state and the actual condition. The process of conversion of information into the proposed action is decision-making[1]. Success of decisions depends primarily on what information is chosen and how conversion is executed.

Decision-making is problem-solving. It involves finding a way to get from some initial situation to a desired goal. It is a mental activity which usually means thinking about how to solve problems that we do not know how to solve at the outset. In other words, problem-solving is a process in which one starts from the initial state and proceeds to search through a problem domain

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using relevant information to identify the sequence of operations or actions that will lead to a desired solution. Thus, information, problem-solving and decision-making are sequentially related and a study of one must necessarily overlap the other[2].

The demand for information is derived from problems and their solution. In organizations demand for information is derived from problems associated with strategic planning, management and operational control. These basic types of management problems led to the development of management science methodologies to create information as raw matrial for problem solving/decision-making.

2. USE OF OPERATIONS RESEARCH TECHNIQUES

Among these methodologies, operations research had its start in logistic and strategic analysis carried out during the Second World War. The complexity of modern warfare is so great that new high-powered methodologies have been necessary to provide the raw material for decision-maaking. A mission or programme associated with offence and defence can involve literally thousands of variables. The techniques of operations research were designed originally to handle these comprehensive problems[3].

Operations research techniques found increasing application in business organizations. Many companies set up operations research and management science departments to aid information gathering activeties by making valid recommendations regarding planning and decision-making.

3. DEVELOPMENT OF INFORMATION SYSTEMS

As organizations grew in size and complexity with denser networks of communication, two issues became pre-eminently important: (i) precise control and speedy flow of information for taking better decisions to improve productivity, efficiency and effectiveness; and (ii) a reduction in organizational cost. The continued and mounting pressure to improve the efficiency and effectiveness of organizations against the back-ground of ever rising cost led the executives to instal electronic data processing (EDP) and then management information systems (MIS), to produce reports for decision-making[4].

3.1 Limitation of Information Systems

Not long after the computer-based information systems were installed in organizations for managerial use, rumbles of dissatisfaction began to be heard. Ackoff[5] in his classic article drew attention to the lack of pay-off from information systems and pointed out what were in his opinion inappropriate design assumptions. In his view the designers ignored the cognitive styles that reflect the ways of functioning that an individual exhibits across perceptual and intellectual activities.

EDP and MIS professionals have approached the problem of desigining information systems to support the decision process aiming at optimization. This approch emphasizes that the decision-makers must have access to all information pertaining to a decision problem. This concept has stemmed from the modern decision techniques, including opertions research, systems analysis, cost-benefit study, etc. These techniques are highly normative, based on theorems, and focus on the logic of optimal choice. The ideal these techniques promote is rationality, which assumes the decision-maker to be technically competent, explicit and consistent in his assessment. A rational individual is one who makes a decison on the basis of :

- a known set of relevant alternatives with corresponding outcomes.
- established rules or sets of relationship that produce a preferred ordering of alternatives, and
- maximizing of the preferances or utilities.

The rational concept in decision-making came under attack by the "Behaviorist School" of "March-Cyert-Simon"[6], as being unrealistic. Simon, who won a Nobel Prize for his work, made an in-depth analysis of rational man. Simon´s main argument was that cognitive limitations prohibit human beings from selecting and assimilating information pertaining to all variables and all possible alternatives. A breakdown of the decision-maker´s cognitive process occurs when the informational demand of the decision problem exceeds his information prcessing capacity. As a result, the decision-maker cannot make a decision that may lead to optimal goal achivement, the ideal of rationality.

4. HUMAN INFORMATION PROCESSING SYSTEM (HIPS)

Newell and Simon[7] have presented a model of human-beings as information processors, which explaines how finite intellectual capabilities result in constrained rationality. A brief overview of the HIPS model makes the point explicit. The HIPS consists of three major subsystems: (1) external memory (EM); (2) short-term memory (STM); and (3) long-term memory (LTM).

(1) External memory (EM) serves as a sensory input device. External stimuli are the inputs which enter through sensors, such as eyes and ears. External stimuli are stored in a buffer memory awaiting processing by the cognitive processor which encodes the stimuli in symbols and filters them for transfer to the STM. EM is the immediate visual field and has access times of the order of 100 ms.

(2) Short-term memory (STM), a working memory, receives symbole stored temporarily in buffer memories and transferred by the cognitive processor. STM evaluates the symbols through

association with the individual mass of accumulated knowledge stored in LTM. After evaluation, when the information is found to be new, STM transfers it to LTM for storing.

The cognitive processor like the central processing unit (CPU) of a computer cycles periodically as it obtains information from the sensory buffers and transfers it to STM. These "recognize-act" cycles which form the basic quantum of cognitive processing are analogous to the "fetch-execute" cycles of a computer. It is estimated that each cognitive processing cycle takes approximately 70 ms.

STM has a very small capacity. According to Miller's[8] experiment, it can accommodate five to seven symbols. Symbols in STM decay very quickly. Therefore, STM needs rehearsal. The symbols are processed sequentially. The ability to recall information in a continuous STM task tends to decline as the storage load is increased.

(3) LTM consists of a large number of stored symbols with a complex indexing system. The related symbols are associated with one another and are stored in clusters called "chunks". A "chunk" is a symbol associated with a set or pattern of stimuli. "Chunks" are hiararchically organized collections of smaller "chunks". In this conception, LTM is a vast network of chunks. Learning and remembering occur as linkages between chunks are established and revised.

There is no limit to the amount of information that can be stored in LTM. However, it is slow in storing information. On the average, it takes about 7 sec. per chunk to assure that the fact is properly linked in the LTM network.

STM can access LTM at a much faster rate (once in each 70 ms cycle). This asymmetry is of great importance in understanding how people function.

Probelm space.

When human-beings are involved in problem-solving, they create a mental model of the problem, piecing together various scraps of information in symbols. This model is referred to as "problem space". A problem space consists of the following:

- Patterns of elements or symbols, each representing a state or way that the task situation may occur.
- Links between elemlents corresponding to the operators that can change one state to another. Operators are legal moves that cause one state to change to another. The links might be casual relationships, reactions, actions, etc.

Human-beings as problem-solvers exhibit cognitive limitations due to slow access to data in LTM, small capacity of STM, and its sequential processing of data, reduction and simplification of the real world problem as abstracted in the problem space.

4.1 Bounded Rationality. March and Simon[9] have argued that because of the cognitive limitations, human-beings cannot make rational decisions. They act rationally only within the boundaries of their perception of the problem and these boundaries generally have been found to be quite narrow compared to the scope of complexity typifying most organizational problems. This led March and Simon to the concept of "bounded rationality".

Because of "bounded rationatity", decisions-makers resort to problem-solving strategies leading to "satisficing", which means that the goal of any decision-maker is to get a good enough answer, not necessarily the best possible one. Problem-solving strategies for "satisficing" follow "heuristics"[10].

"Heuristics" are rules of thumb or simplification that reduce or limit search in large problem spaces. Unlike algorithms, heuristics do not guarantee correct solution.

Keen and Scott Morton[11] suggest that one can usually improve one's heuristics, although at the often unacceptable cost of increased cognitive effort. However, computer-based decision support systems (now known inter-changeably as expert system or knowledge system) can aid the decision-makers to improve their heuristics.

5. EXPERT SYSTEM AND APPLICATION OF AI TECHNIQUES

The HIPS model shows how human cognitive system works. Events in the world produce stimuli that impinge upon us. We sense stimuli and store them in buffers. Some stimuli are transferred to STM (working memory). The transfered stimuli activate the "if" portion of a production rule. The "then" of the production then indicates appropriate action. The actions are implemented by the motor system and are observed as responses.

The HIPS model led the artificial inteligence (AI) researchers to focus their attention on the role that "if-then" rule playes in human cognition. They created a programming language called "production system". Production system consists of two parts: (1) production rule or "if-then" statements, and (2) a working memory. Put in another way, a production rule is an instruction for "recognize-act" processor. Production rules (or simply production) are applied to the working memory. If they succeed, then they ordinarily contribute some new information to memory. This very basic concept led the AI researchers to develop expert systems or knowledge systems to help decision-makers improve their heuristics.[12]

5.1 Concept of Expert System - An expert system is an intelligent computer program that uses knowledge and inference procedures to solve problems that are difficult enough to require significant human expertise. Knowledge necessary to perform at such a level, plus the inference procedures used, can be thought of as a model of the expertise of the best practitioners of the field[13].

The knowledge of an expert system consists of facts and heuristics. "Facts" constitute a body of information that is widely shared, publicly available, and generally agreed upon by experts in a field. The "heuristics" are mostly private, little discussed rules of good judgement (rules of plausible reasoning, rules of good guessing), expert-level decision-making in the field. The performance level of an expert system is primarily a function of the size and quality of a knowledge base it possesses[13].

6. ARCHITECTURE OF AN EXPERT SYSTEM

An expert system is a computer-based system that contains two basic parts : (1) Knowledge base and working memory; and (2) Inference system, including interface subsystem.[14]

6.1 Knowledge Base. An expert system is built to address problems in a specific problem domain. The builder of an expert system, who is commonly referred to as knowledge engineer, acquires knowledge of the subject field from an expert. The expert is asked to describe the strategy that he has followed in the resolution of the problems encountered recently. When the knowledge of an expert is gathered, disected and analyzed closely, the knowledge engineer is able to discern a certain pattern in linking together the objects based on certain characteristics, cause-effect relationship, and the logical inferences about the plausible causes of a certain action.

Here, by an expert is meant "an individual who is widely recognized as being able to solve a particular type of problem that most other people cannot solve nearly as efficiently and effectively".[15]

AI researchers have developed five different approaches to represent the human knowledge base in an expert system's database:

- Semantic network
- Object - attribute - value (O-A-V) triplet
- Rules
- Frame
- Logical expressions

A brief overview of semantic networks and O-A-V triplet, which are most commonly used in expert systems, is presented here.

Semantic network (or semantic net) is a collection of objects called nodes. The nodes are connected together by arcs or links. Ordinarily, both the nodes and links are labelled.

Nodes are used to represent objects and descriptors. Objects that can be seen or touched may be physical. Objects can also be conceptual entities, such as acts, events or abstract categories.

Descriptors provide additional information about objects. Links relate objects and descriptors. A link may represent any relationship. Common links include the following :

"Is-a" link is often used to represent the class/instance relationship.
A second common relationship is the "has-a" link, which is used to identify nodes that are properties of other nodes. "Has-a" link shows part - subpart (whole-part) relationship.

Some links are definitional. When two objects are linked together by relationships which represent the purpose of the objects, then it is definitional.
Other links capture heuristics knowledge. This enriches the network by providing additional paths.

Semantic network has certain advantages : (i) it is flexible. New nodes and links can be defined when needed; (ii) it has a feature of "inheritance". This provides ability to one node to inherit the characteristics of other nodes. Property inheritance is one implication of an "is-a" relationship.

This knowledge representation scheme has come out of the AI research in human cognition. Thus, the concepts of semantic nets, links. nodes and inheritance hierarchies, are all related to research into how humans store information in LTM.

(2) Objects-attribute-value (O-A-V) triplet is another common method to represent factual information. Objects may be physical entities or they may be conceptual. Attributes are general characteristics or properties associated with objects. Values represent specific nature of an attribute in a particular situation.

Representing knowledge with O-A-V triplet is a specialized case of the semantic network approach. In this scheme, links are represented by just two relationships. The object attribute is a "has-a" link, and the attribute value is an "is-a" link. Nodes in the net are objects, attributes or values.

Of the remaining three methods of knowledge representation, rules and frames are very closely related with semantic net and O-A-V triplet. The third, logical expression, represents knowledge in a different manner.

6.2 Inference System. Inference system guides in the use of facts and rules stored in the knowledge base and helps draw inferences and controls the reasoning process of the user. This system, therefore, stands between the user and the knowledge base.

Inference system performs two major tasks : (i) it examines existing facts and rules and adds new facts whenever possible; and (ii) it decides the order in which inferences are made. Inference and control consists of the following:

6.2.1 Inference

- Modus ponens - a logical rule used for reasoning.
- Reasoning about uncertainty - by permitting handling of incomplete or unknown information.
- resolution which consists in determining validity of new facts through a set of logical statements.

6.2.2 Control: Inference system addresses the following problems through its control subsystem:

- Provides a way for the reasoning process to begin.
- Resolves conflicts that occur when alternative lines of reasoning emerge.

The control system follows the following strategies:

- Backward and forward chaining. In "backward chaining", the system starts at the goal and works backwards through the subgoals in an effort to chose an answer. In "forward chaining", premises of the rules are examined to see whether or not they are true, given the information on hand, and then conclusions are added.

- Depth-first versus breadth-first search. In depth-first search, the inference system produces subgoal. From "action" the system backs-up "means" and then "distance". Searching for detail-first is the theme of back-chaining in "depth-first" manner. A breadth-first search examines all premises in a rule before exploring for greater detail.

Monotonic-versus-non-monotonic reasoning. Some inference systems utilize monotonic or non-monotonic reasoning processes. In a monotonic reasoning, all values concluded for an attribute remain true for the duration of consultation session. Facts that become true remain true, and the amount of true information in the system grows steadily or monotonically.

In a non-monotonic reasoning system, facts that are true may be retracted. Planning is a good example of a problem type that demands non-monotonic reasoning. A plan is conceived and evaluated. When more information are available that throw light on

newer variables that were ignored initially, the decision is revised. Thus, these decisions and their consequences are retracted.

Inference and control mechanisms of the inference system are, therefore, important components which permit the use of facts and rules contained in the knowledge base of an expert system.

7. USE OF EXPERT SYSTEMS IN LIBRARIES.

It is important to realize that most decision making activities that take place in libraries represent a chronic condition of cognitive strain[16]. It is because the decision problems are complex involving a large number of variables related in unknown manner with discrete values and stochastic properties. Since librarians as human beings have limited ability to process all relavant information, they may adopt simpler models using a few broad categories of information even when such broad categorization may suppress important information. Simplistic approaches to modeling of problems pursued by librarians may not be compatible to the goals espoused by them. Therefore, librarians are the most potential candidates to be supported by expert systems.

Expert systems can be used in a variety of contexts and by different levels of management in libraries:

Senior Library Managers :

For the top managers in libraries who are concerned with planning, organizing and coordinating, information monitoring and reporting are necessary for continuous evaluation against actual events of the expectations that underlie the decisions. Like any executive in a competitive business organization, librarians always build an organized feedback - reports, figures, studies into their decisions to monitor anticipated results. An expert system can be built for use as a work station to control and monitor for decisions without actual going out to look at the scene of action.

An expert system as a work station may be helpful in exploring the implications of various fast breaking developments especially in library resource sharing networking environment.

Operational groups :

The various operational groups within a library including information providers, cataloguers, collection builders are potential candidates to be supported by expert systems. Recent literature on information science reports the development of a number of experts systems to support operational tasks in the library.

Todeschini and Farrell[17] report the building up of an expert system for quality control in bibliographic databases that can identify errors in the intellectual decisions made by the indexers when categorizing documents in a-priori category scheme. Similarly Hyrpee and Olander[18] describe the project undertaken to develop two expert systems with the main purpose of choosing access points, identify main and added entries. It is envisioned that such a system could take over some of the workload, allowing human expert catalogers to concentrate on the problematic items.

Conclusions:

Exepert Systems represent human expertise in a particular problem domain in order to act as surrogates for the human experts and therefore assist people who do not have access to an expert. Expert systems do not necessarily replace people, but serve as intelligent assistant, improving productivity and quality of decision making.

Even though expert systems are just beginning to enter into the fields of library and information science, we can foresee a bright future for their application in all managerial and operational functions of libraries. Indeed, Artificial Intelligence research is clearly pushing ahead on a broad front and making slow but steady progress on every thing from practical translation systems to computer programs that can synthesize human speech or prepare abstract from the full text. As a result of these research efforts information service may not be restricted to simple reference, document or fact provision, but may become extreme user oriented to the extent of providing information packaged in a form compatible to an individual user's goals, knowledge, task structure and mental capability.[19]

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